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WAVE PRESSURE CALIBRATION OF WAVE-WIND-CURRENT
RESEARCH FACILITY

Donald Bellows

Scripps Institution of Oceanography

TECHNICAL REPORT

WAVE PRESSURE CALIBRATION
OF
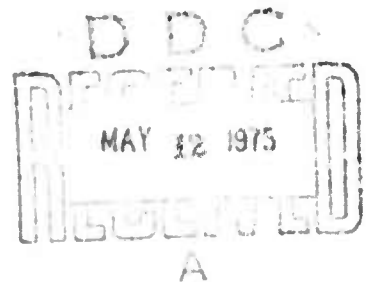WAVE-WIND-CURRENT
RESEARCH FACILITY

Donald Bellows

SCRIPPS INSTITUTION OF OCEANOGRAPHY
University of California, San Diego
Dr. William A. Nierenberg, Director

ADVANCED OCEAN ENGINEERING LABORATORY

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Advanced Engineering Division
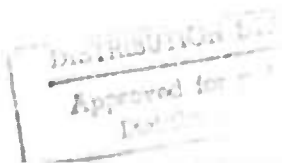
ARPA Order No. 1348

Approved by: _____
Dr. Fred N. Spiess, Principle Investigator

November 1, 1970

Advanced Ocean Engineering Laboratory Report No. 12

Contents   Page

Introduction

This report gives the results of the wave pressure
calibration of the Wave-Wind-Current Research Facility
(see Advanced Ocean Engineering Laboratory Report No.
11). It is anticipated that most of the model testing
in the facility (wave channel) will be done with 1/100
scale models. This corresponds to a 1/10 scaling of the
wave period T, and thus the periods of interest are from
T=0.5 seconds to T=2.0 seconds (5 seconds to 20 seconds
in the ocean). Periods longer than 2.0 seconds are shown
on some of the graphs just as additional information. All
measurements for this report were made at mid-length of
the channel. The water depth was approximately 1 3/4
meters.

Paddle Position

An attempt has been made, by moving the position of the
wave paddle north top pivots, to produce wave pressures
that correspond to deep water waves. The results of
these attempts are shown in Figures 1 thru 4. These
figures give the deviation of the measured wave pressure
from the calculated deep water wave pressure using four
different positions of the paddle pivots. Two piezo-
electric pressure sensors (9.5 mm diameter x 19 mm long)
were used, one at a depth of 25 cm and the other at a
depth of 150 cm, both being positioned at the center of
the channel. The measurements were made using a Sanborn
recorder. When the paddle pivot is set back 9 cm,
referred to its original installed position, the shallow
sensor (d=25 cm) shows good agreement with a deep water
wave for the entire range of periods $1.3 \le T \le 2.5$ seconds.
However, it is only in the range $1.3 \le T \le 1.5$ seconds that
both the shallow and the deep sensor show good agreement

with deep water wave theory. But this is as it should
be since, for this particular wave channel, waves with
T>1.5 seconds are not deep water waves, but instead fall
in the intermediate depth range. It appears, then, that
a good position for the paddle pivot is at 9 cm back.

Stability

The task of model testing in the channel will be easier if
the wave regime remains steady during the time that data
is being taken. Figure 5 gives the variation in wave
height for a wave height H of approximately 76 mm. It
can be seen from Figure 5 that periods from 0.5 to 1.0
seconds show appreciable variation in wave height, except
for T=0.9 seconds which has a relatively low variation.
The range, then, for steady waves is T=0.9 seconds and
$1.1 \leq T \leq 4$ seconds over which the wave height will remain
steady within 5 mm for at least 5 to 10 minutes.

Relatively high variation in wave height is seen at
T=0.5, 0.7, and 1.0 seconds. These periods seem to
correspond to transverse resonances in the channel.

Transverse Variation

At one time shortly after beginning checkout of the
channel, there was noticed an appreciable difference
between the wave height as observed at the glass wall
of the channel and at the center of the channel, the
height at the center being lower by as much as 25 mm.
To get a better look at this effect, after adjustments
of the absorber at the end of the tank, measurements were
made at nine different stations across the width of the
channel.

Figures 6 thru 10 show the results of these measurements
using five different wave periods and with the wave

paddle pivot back 9 cm. A variation in wave height
of 25 mm was observed, but only at $T=0.9$ seconds. The
maximum variation for any of the other periods was
about 3 mm (of the order of the variability shown in
Figure 5).

Wave Pressure as a Function of Depth

A deep water wave is a wave such that

$$\frac{h}{L} \geq 0.5$$

where
h = water depth
L = wave length

The relationship between wave length and wave period,
for a deep water wave, is given by:

$$L = \frac{gT^2}{2\pi} = 5.12T^2$$

For the water depth of 1 3/4 m in the channel the
conditions for a deep water wave are:

$$T \leq 1.5 \text{ seconds}$$

It appears from the previous work that a good setting
of the paddle pivot is 9 cm back. Wave pressure
measurements were made at this paddle setting. A
pressure sensor was moved from a depth of 25 cm to a
depth of 150 cm in increments of 25 cm. These points
give the measured curve in Figures 11 thru 16. The
theoretical deep water curve was obtained by:

$$P_d = P_o e^{-kz}$$

where
P_d = pressure at depth
P_o = pressure at surface
k = wave number = $2\pi/L$
z = depth of interest

All pressures are given in mm of water so that P_o is simply
the wave height in mm.

It will be noticed that in Figures 13 thru 16 a third curve has been plotted. This is the curve for wave pressure in intermediate depth water, i.e., water for which:

$$.05 < \frac{h}{L} < 0.5$$

The wave pressure is given by:

$$p_d = p_o \left[\frac{\cosh k\ (z+h)}{\cosh kh} \right]$$

It was mentioned at the beginning of this report that, for the water depth of 1 3/4 m, waves with T>1.5 seconds are not deep water waves. Figures 14 thru 16 show, indeed, that the measured results are in better agreement with the intermediate depth theory than with the deep water theory.

Conclusions

1. The best setting for the paddle pivot is at 9 cm back.

2. Waves with $0.5 \leq T < 0.9$ and $T=1.0$ are relatively unstable. Waves with $T=0.9$ and $1.1 \leq T \leq 4$ are relatively stable.

3. For $T=0.9$ seconds the variation in wave height across the width of the channel is about 25 mm. However, there is a region (the back half of the channel) in which the variation is only about 7 mm. For $T=1.3$ seconds thru $T=2.5$ seconds the maximum variation anywhere across the channel is about 3 mm.

4. The measured wave pressure versus depth agrees closely (within 4 mm) with the theoretical, either deep water or intermediate depth water, whichever applies for the particular wave period.

The waves that are stable remain so for extended periods of time. The waves that are unstable are unstable at all times including right after startup. Tests can be conducted in the unstable waves provided that the model response record is synchronized with the wave record.

Deviation of Measured Wave Pressure From
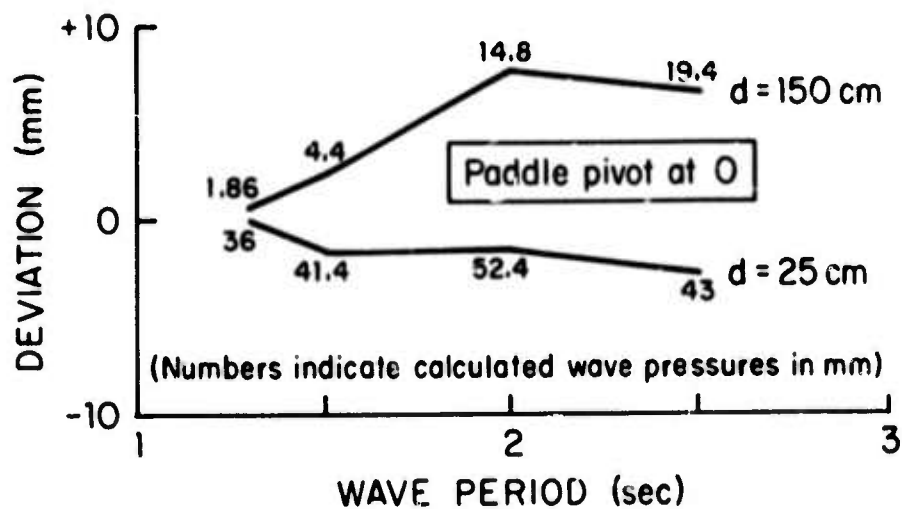Calculated (Deep Water) Wave Pressure

Figure 1

Deviation of Measured Wave Pressure From
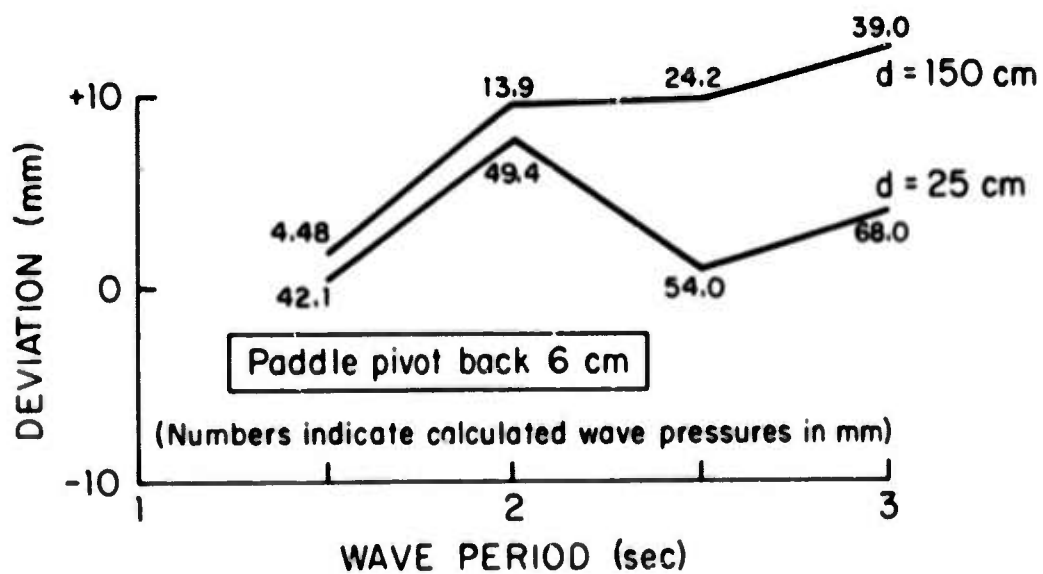Calculated (Deep Water) Wave Pressure

Figure 2

Deviation of Measured Wave Pressure From
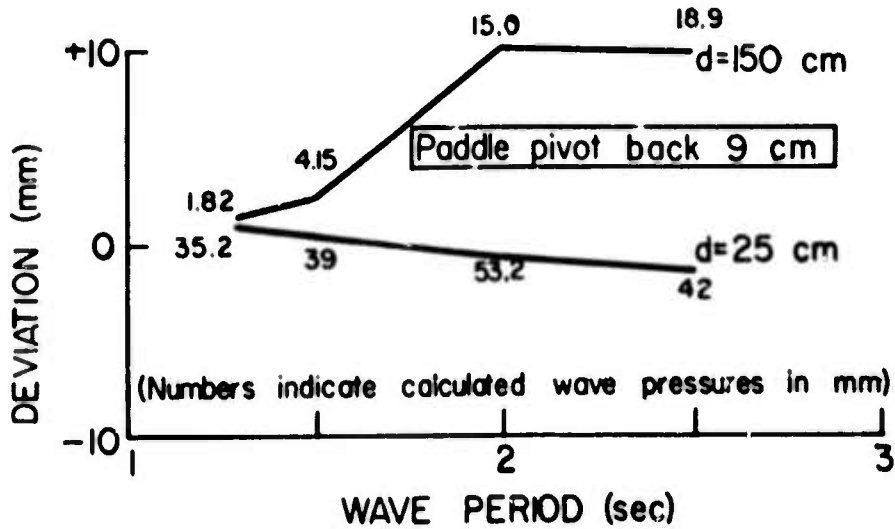Calculated (Deep Water) Wave Pressure

Figure 3

Deviation of Measured Wave Pressure From
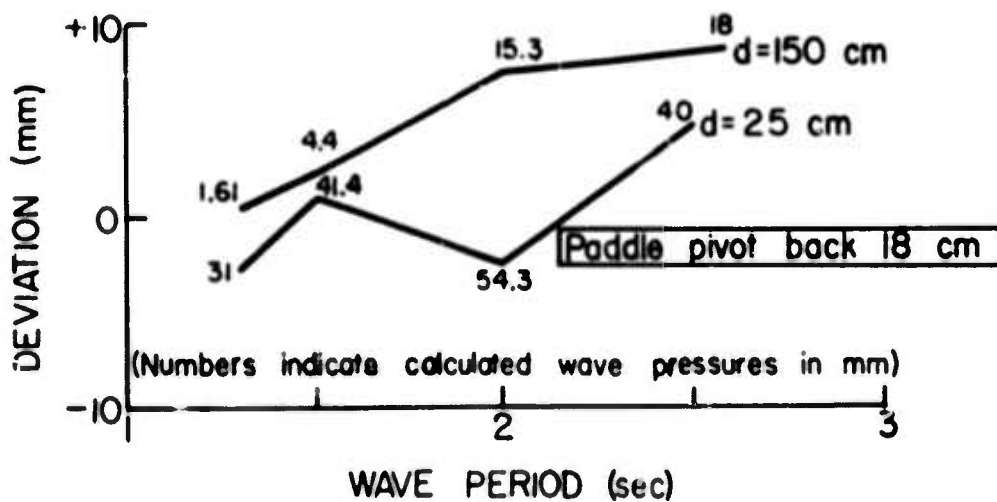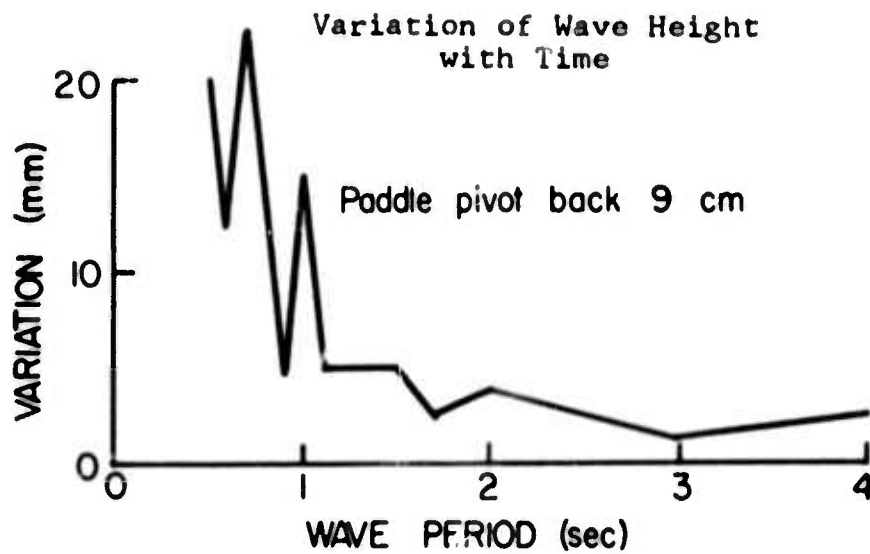Calculated (Deep Water) Wave Pressure

Figure 4

Variation of Wave Height
with Time

20

VARIATION (mm)

Paddle pivot back 9 cm

10

0
0   1   2   3   4

WAVE PERIOD (sec)

Figure 5

Variation of Wave Height
Across Width of Channel

50

WAVE HEIGHT (mm)

30

T= 0.9 sec

10
1   2   3   4   5   6   7   8   9
STATIONS   ₵   (25 cm apart)
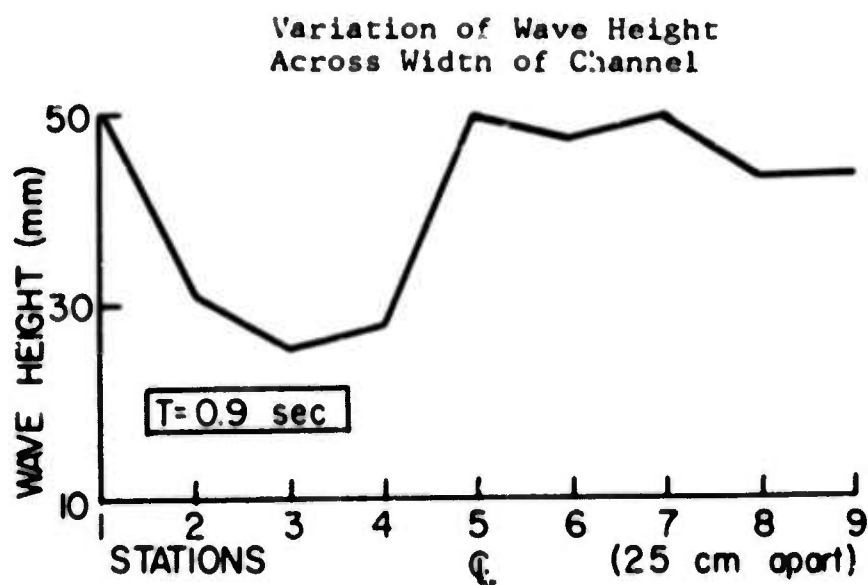
Figure 6

Variation of Wave Height
Across Width of Channel
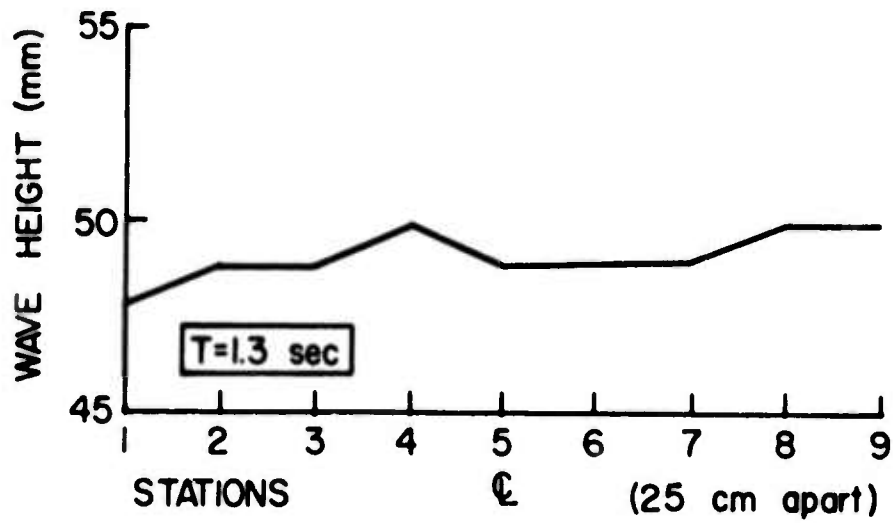
Figure 7
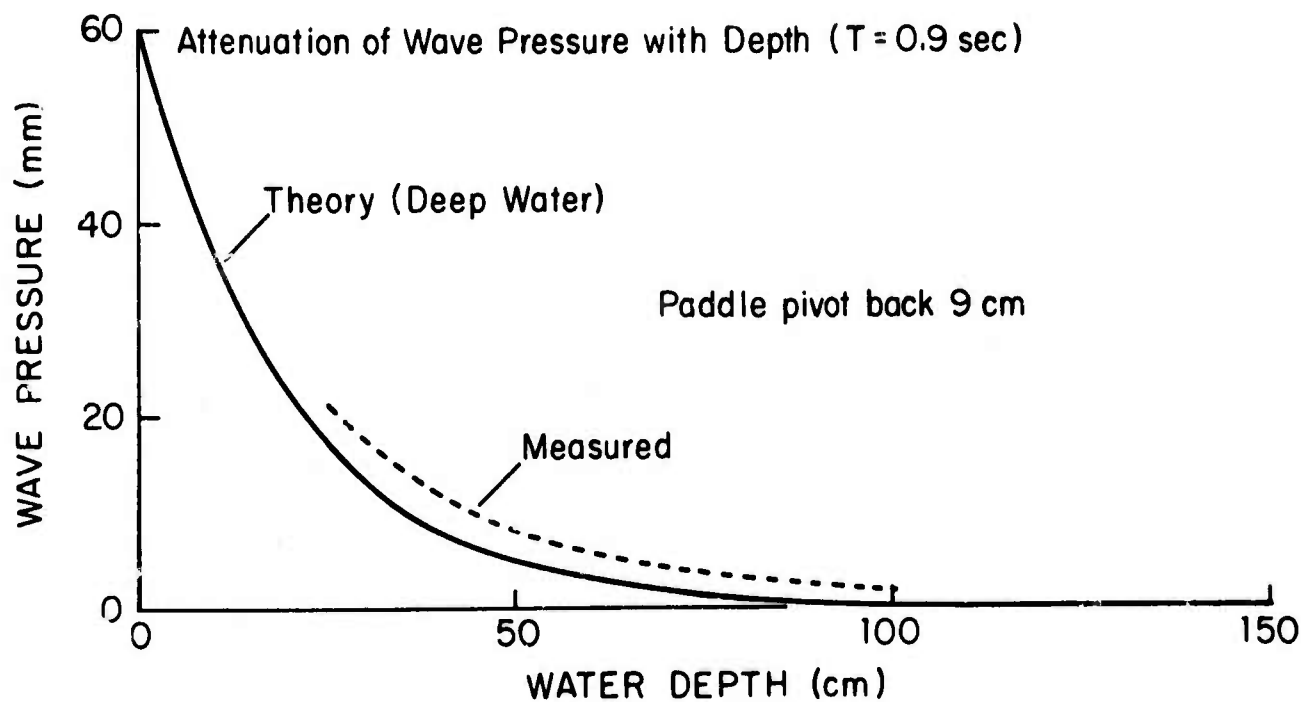
Variation of Wave Height
Across Width of Channel
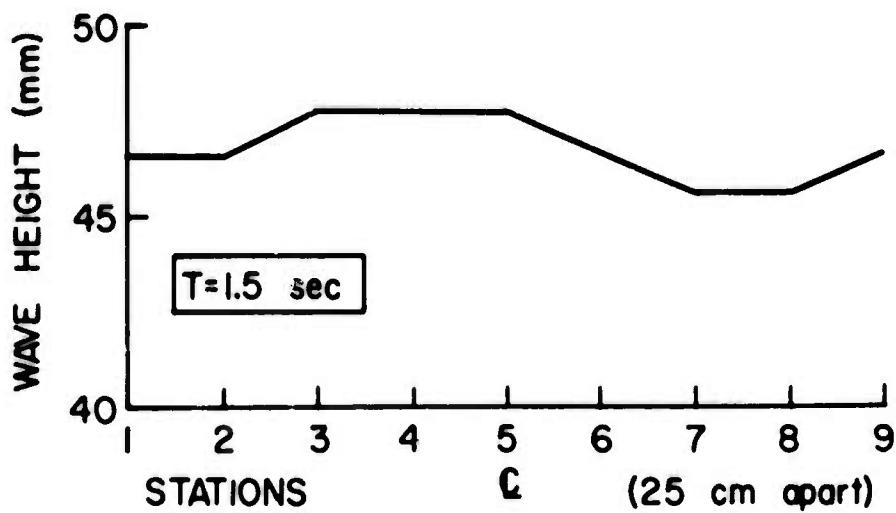
Figure 8

Variation of Wave Height
Across Width of Channel
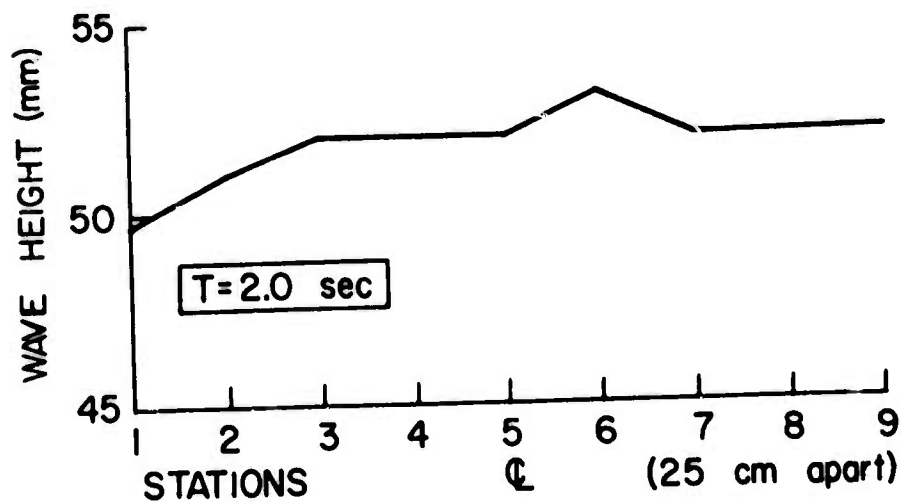
Figure 9

Variation of Wave Height
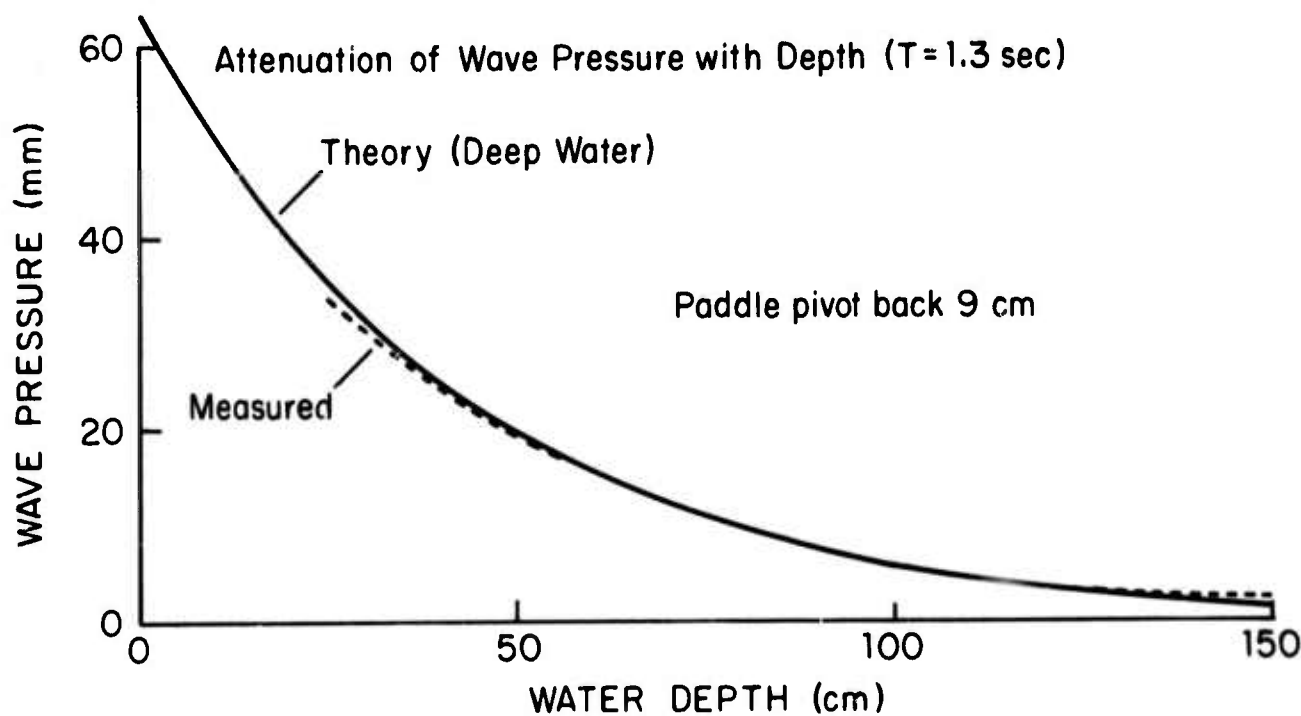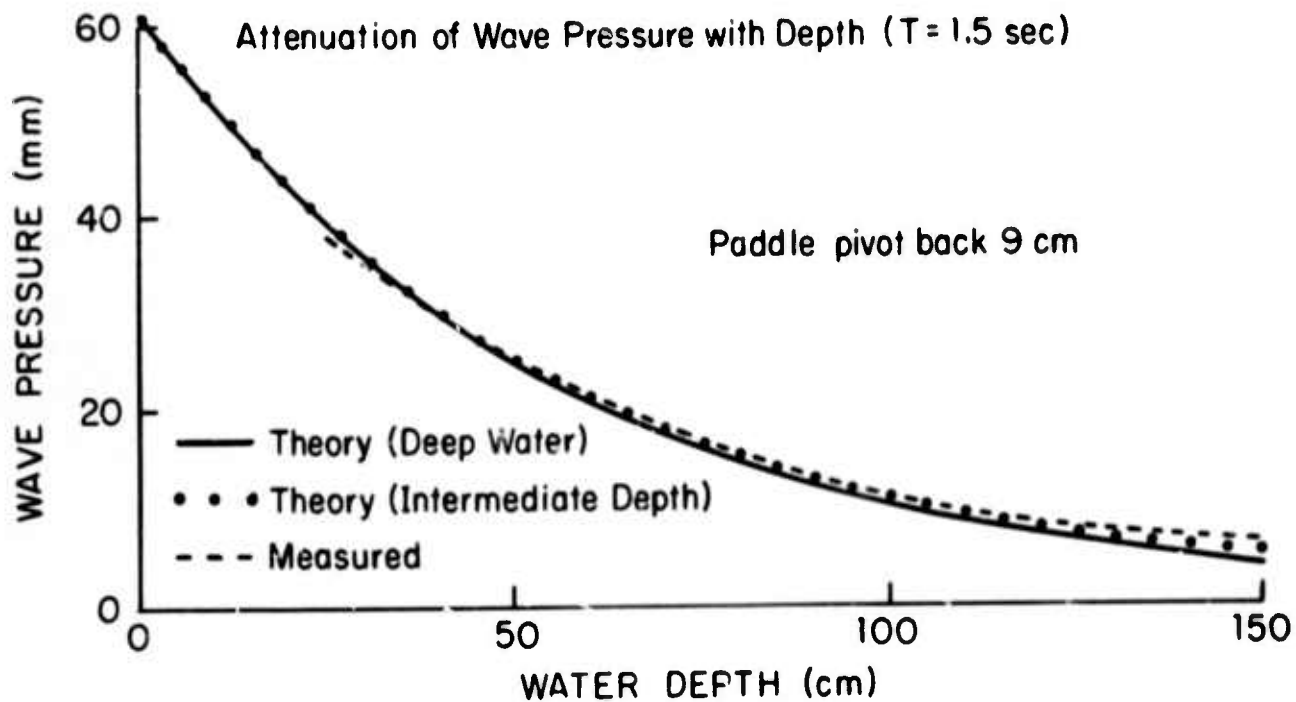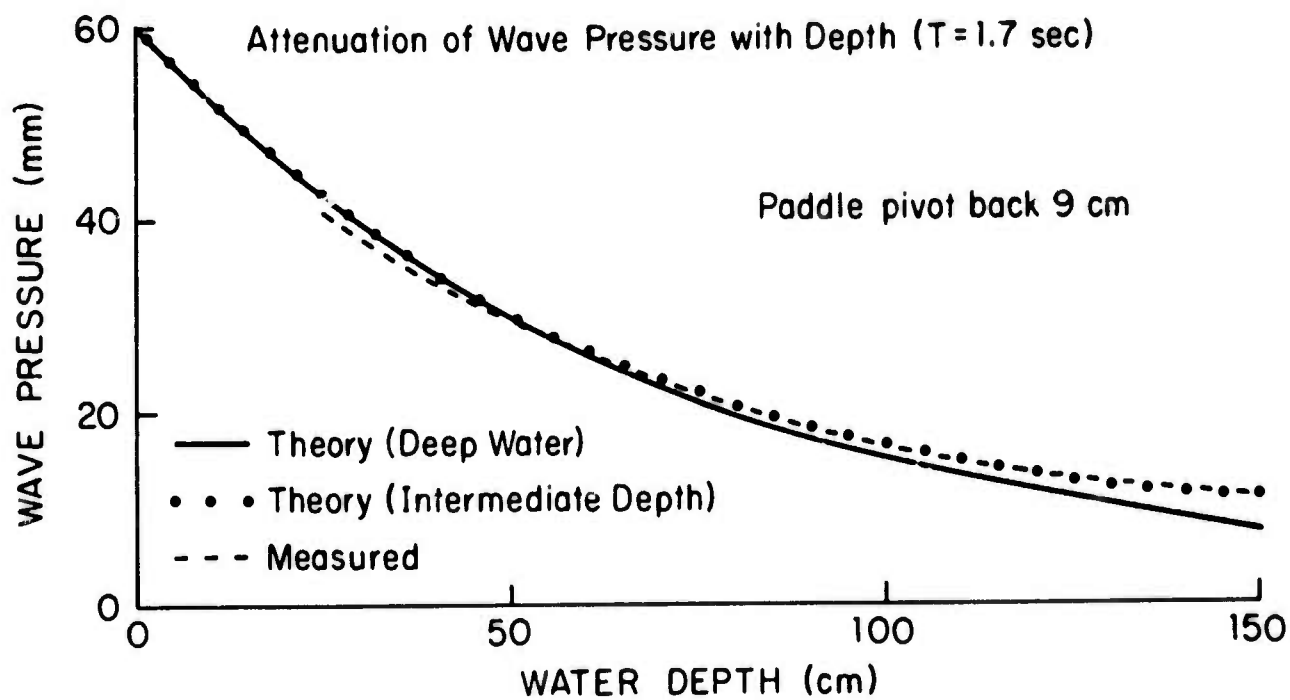## Across Width of Channel
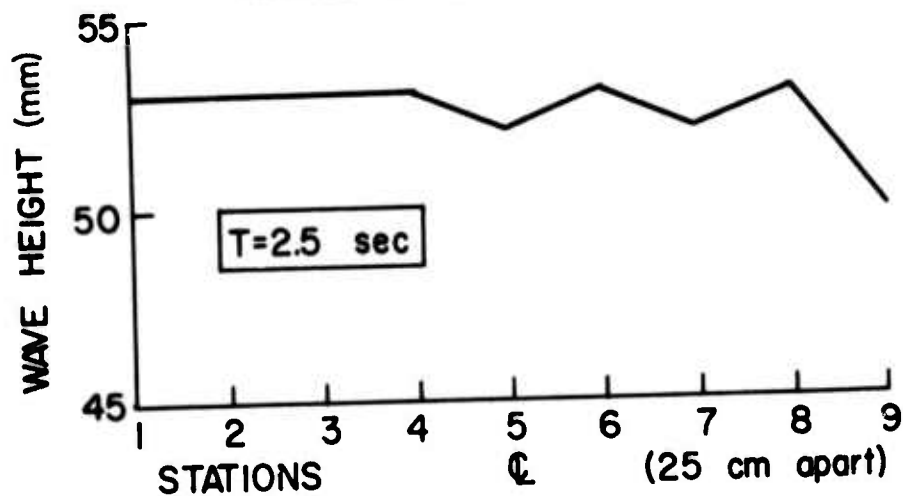
Figure 10

Figure 11

Figure 12

Figure 13

Figure 14

Figure 15

Figure 16